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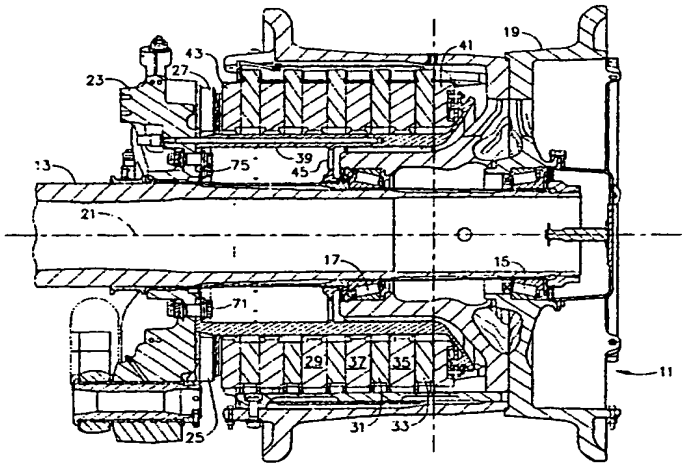
(54) Title: MULTI-DISC BRAKE STRUCTURAL ASSYMMETRY



(57) Abstract: A multi-disk brake and wheel assembly (11) includes a cantilevered wheel axle (13) with a wheel (19) journalled for rotation about the axle and a plurality of brake disks (31, 33, 35, 37) radially surrounding the axle. Alternate ones of the brake disks are angularly fixed to the wheel for rotation wherewith and the disk stack is axially confined between an end disk (41) at one axial end and a pressure plate (43) at the opposite axial end of stack. An axially asymmetrical vibration-reducing torque tube (39) radially surrounds the axle and axially spans the brake disks with intervening ones of the brake disks angularly fixed to the torque tube. The torque tube has a radially inwardly extending annular support flange (45) intermediate the one and other end for augmenting the support of the tube on the stationary member. Cut-outs (47, 49, 51, 53, 55, 57) in support flange (45) impart dynamic asymmetry to the torque tube and displace its elastic center off-axis of the brake discs, reducing the brake vibration amplitudes.

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MULTI-DISC BRAKE STRUCTURAL ASSYMMETRY

BACKGROUND OF THE INVENTION

[001] This application claims priority under 35 U.S.C. §119(e) of U.S. Provisional Application No. 60/317,012 filed on September 4, 2001, the entire contents of which are herein incorporated by reference.

Field of the Invention

[002] The present invention relates generally to brake systems and more particularly to multi-disk brake systems and techniques for reducing vibrations which occur in such multi-disk brake systems during a braking event.

Description of the Related Art

[003] A multi-disk brake system typically has a brake disk stack having alternate disks keyed to and rotatable with a wheel, while intervening disks are keyed to the stationary brake housing. Multi-disk brake systems are frequently used in aircraft. The non-rotating disks are supported by a torque tube which is fixed to the brake housing and extends in an outboard direction in a generally cantilevered manner coaxially surrounding the wheel axle. An end disk at the outboard end of the torque tube is both rotationally and axially fixed to the torque tube. When one or more brake actuators are energized, corresponding pistons force a brake pressure plate to compress the disk stack between the pressure plate and end plate, slowing the vehicle. The non-rotating brake structure typically has strong radial and torsional vibration modes that are concentric with the axle. The vibrations result in passenger annoyance and may cause brake control feedback interference. Extended repetitive vibrations events may cause excessive wear, fatigue, or ultimate structural failure. Additional structural features may be added to reduce vibration, but add to the overall weight of the system. It is desirable to reduce braking system vibrations without adding significantly to the weight of the braking mechanism. It is also desirable to provide a braking system which reduces brake-induced vibration, torque oscillations, hydraulic pressure

exhibits asymmetric stiffness.

[006] An advantage of the present invention is that adverse vibration associated with the torque tube is reduced or avoided without increasing the torque tube mass. Also, conductive transfer of brake heat to the axle is reduced.

BRIEF DESCRIPTION OF THE DRAWINGS

[007] Fig. 1 is a cross-sectional view of a multi-disk braking mechanism and wheel assembly illustrating the orientation of the torque tube relative to the rest of the brake and the interfacing axle and wheel;

Fig. 2 is an end view of the torque tube of Fig. 1 from the right side thereof illustrating unequal cutouts in the torque tube support structure providing asymmetry; and

Fig. 3 is a view in cross-section along line 3-3 of Fig. 2.

Corresponding reference characters indicate corresponding parts throughout the several drawing views.

DETAILED DESCRIPTION OF THE INVENTION

[008] Referring now to the drawings and particularly to Fig. 1, there is shown an aircraft wheel and brake assembly 11 having a cantilevered axle 13 which is fixed to the aircraft landing gear. The axle 13 has tapered roller bearings 15 and 17 rotatably supporting a wheel rim 19. Wheel rim 19 is thereby journalled for rotation about the axle 13 axis 21. The wheel rim 19 has conventional flanges for receiving the bead of a tire (not shown). A brake housing 23 includes a plurality of actuators such as hydraulically actuable pistons 25 and 27. A brake disk stack 29 has alternate disks such as 31 and 33 fixed to and rotatable with the wheel rim 19 while intervening disks such as 35 and 37 are stationary and fixed to housing 23 by way of torque tube 39. Torque tube 39 may include longitudinal ribs providing a keying arrangement to angularly fix alternate ones of the disks and end disk 41 may be fixed to the torque tube 39 both axially and angularly. When braking is initiated, actuators 25 and 27 (perhaps along with a plurality of similar annularly disposed actuators)

holes 47 and 49 is different from the angular spacing between holes 47 and 51. Other non-uniform hole patterns are clearly possible. These radially disposed non-uniform holes impart asymmetry to the support flange 45 and to the entire torque tube 39. The result is a torque tube with an asymmetric radial stiffness.

[011] A volume is symmetrical with respect to a given plane (a plane of symmetry) if, to every point P of the volume, there is a second point P of the volume such that the line PP is perpendicular to the plane and divided into two equal parts by the plane. When a volume has two planes of symmetry, the centroid of the volume must lie on the line of intersection of those two planes. If the volume is of uniform density, the center of gravity (and center of mass) is located at the centroid. Conventional torque tubes are generally cylindrical and symmetric having several planes of symmetry all passing through the axis of the cylinder which axis corresponds with the axis of the wheel axle and the axis of the stack. When the several planes all pass through the central axis, the tube has axial symmetry. A volume having at most one plane of symmetry is asymmetrical. If there are two planes of symmetry and they intersect off-axis, that is, if at most one plane of symmetry passes through the axis, the tube is axially asymmetric. Torque tube 39 is axially asymmetric due to the non-uniformly distributed hole pattern of openings 47, 49, 51, 53, 55 and 57.

[012] In summary, the present invention adds asymmetrical cut-outs to the torque tube in the area of the support flange. The cut-outs impart dynamic asymmetry and shift the elastic center of the torque tube to an off-axis location, reducing brake vibration amplitudes. The primary torque tube loads bypass the effected structure. Asymmetry may also be obtained by varying the thicknesses at other sections of the torque tube. These machined features do not increase mechanical complexity and do not necessarily increase weight.

4. The multi-disk brake and wheel assembly of claim 1, wherein the torque tube includes an annular radially inwardly extending support flange (45) axially intermediate the torque tube ends for supportingly engaging the axle, the support flange including a plurality of non-uniformly angularly disposed holes (47, 49, 51, 53, 55, 57) for imparting asymmetry to the support flange and to the torque tube.

5. A torque tube (45) for angularly fixing alternate disks (35, 37) in a multi-disk brake assembly and limiting axial movement of the alternate as well as the intervening disks (31, 33), comprising a generally cylindrical annular member formed as a volume of revolution about an axis (59) and symmetrically deviating from a volume of revolution by having a plurality of ribs (61, 63) for keying the alternate disks to limit rotation thereof, a plurality of flanges (65, 67, 69) near one end for angularly and axially fixing an end one (41) of the disks, and a plurality of fastener (71) receiving apertures near an opposite end for fixing the torque tube to a braking structure, the torque tube further asymmetrically deviating from a solid of revolution to impart asymmetric radial stiffness to the torque tube.

6. The torque tube of claim 5, wherein the torque tube center of gravity is located off the axis of revolution.

7. The torque tube of claim 5, further comprising a radially inwardly extending annular support flange (45) located along the axis for augmenting the support of the tube on the braking structure, the torque tube asymmetrically deviating from a solid of revolution solely within the support flange.

8. The torque tube of claim 7, wherein the support flange includes a plurality of holes (47, 49, 51, 53, 55, 57), certain ones of which (49, 51, 53, 55, 57) are circular and others of which (47) are non-circular thereby imparting asymmetry to the support flange and to the torque tube.

9. The torque tube of claim 7, wherein the support flange includes a plurality of holes (47, 49, 51, 53, 55, 57), at least two of which (47,

different areas thereby imparting asymmetry to the support flange and to the torque tube.

15. The torque tube of claim 12, wherein the annular support flange has a radially inner surface (77) for engaging a wheel axle and a web portion (79) radially outward of the surface including a plurality of non-uniformly angularly disposed holes (47, 49, 51, 53, 55, 57) for imparting asymmetry to the support flange and to the torque tube.

INTERNATIONAL SEARCH REPORT

Information on patent family members

Int tional Application No
PCT/US 02/28002

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5205382 A	27-04-1993	DE 69105902 D1	26-01-1995
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different areas thereby imparting asymmetry to the support flange and to the torque tube.

15. The torque tube of claim 12, wherein the annular support flange has a radially inner surface (77) for engaging a wheel axle and a web portion (79) radially outward of the surface including a plurality of non-uniformly angularly disposed holes (47, 49, 51, 53, 55, 57) for imparting asymmetry to the support flange and to the torque tube.